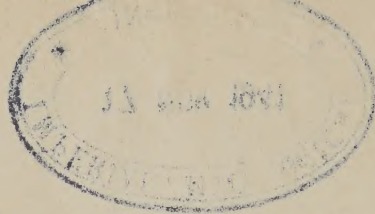


Studies on the Control of Internal Breakdown of Table Beets by the Use of Boron

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STUDIES ON THE CONTROL OF INTERNAL BREAKDOWN OF TABLE BEETS BY THE USE OF BORON¹

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In 1937, Raleigh and Raymond² made a brief report of greenhouse and field experiments on the control of a physiological breakdown of table beets, which had caused serious losses to growers in Ontario County and in other counties of western New York, where the crop is grown for canning. They pointed out that the breakdown began within the enlarged roots, as shown in figure 1, and was not external as was sometimes indicated



FIGURE 1. BEETS SHOWING INTERNAL BREAKDOWN

A red screen was used to make red areas appear white

when beets were examined late in the year and the surface of the beet appeared girdled. This injury is called *dry rot* by many growers in New York State; *internal black spot*, by Walker et al.,³ and *canker*, by Bouquet.⁴

During dry seasons a large part of the beets grown in the Ontario County area showed some breakdown. The majority of these soils tested between pH 7.2 and 7.6. In many places the beets grown on the higher, drier

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²Raleigh, G. J., and Raymond, C. B. A preliminary note on the control of internal breakdown in table beets by the use of boron. Amer. Soc. Hort. Sci. Proc. 35:526-529. 1937.

³Walker, J. C., Jolivet, J. P., and McLean, J. G. Internal black spot of canning beets and its control. Canning age. 19:489-491. 1938.

⁴Bouquet, A. G. B. Determination of usefulness of boron in prevention of beet canker. Oregon State College. Mimeographed chart. 1938.

spots in the field have been practically worthless. The breakdown also causes severe losses to canners because of the increased labor cost of sorting and removing broken-down areas in the beets.

Greenhouse experiments, using soil from a field in Ontario County, where breakdown was severe in 1936, indicated that borax applied at the rate of 10 pounds to the acre reduced the amount and severity of the injury.

In field experiments in 1937, breakdown was found in but one of four fields on which borax was applied. In that field, borax applied at the rate of 5 pounds to the acre in trenches alongside the row during the early stages of growth gave almost complete control of the breakdown. From 50 to 88 per cent of the beets in this same field, which were not fertilized with borax, showed severe breakdown. Most of the beets in the areas not treated with borax were injured at the growing points, a symptom common to many plants affected by boron deficiency. Typical foliage symptoms of boron deficiency in the beet are shown in figure 2.



FIGURE 2. BORON DEFICIENCY, AS INDICATED BY THE DEAD GROWING POINT, THE DEFORMED INNER LEAVES, AND THE RELATIVELY PROSTRATE FOLIAGE

At the time these preliminary experiments were made, the cause of the breakdown was not known, and five minor elements other than boron were used without apparent effect. Subsequent work has been confined largely to experiments with boron. The results are given under the general headings "Field Experiments" and "Greenhouse Experiments".

FIELD EXPERIMENTS

Field applications of borax were broadcast in most instances before beets were seeded, or borax was applied in trenches alongside the row soon after the seedlings had made sufficient growth to make the work possible. The experiments were conducted on a number of farms in Ontario County. Plots were located on lower parts of fields, as well as on the higher areas where breakdown is more commonly found. On most of these plots, strains of the Detroit Dark Red variety were grown.

EXPERIMENTS IN 1938

Borax was applied at the rate of 5, 10, and, in some places, 15 pounds to the acre in trenches about 4 inches deep, 4 inches from the row of beets, in the early stages of growth, as had been done the previous year. The applications were made on 15 farms. On another farm, chosen because of its proximity to the plot where borax controlled breakdown satisfactorily in 1937, small replicated plots treated with 0, 5, 10, and 25 pounds of borax to the acre were planted to beets, carrots, muskmelons, cabbage, cauliflower, and rutabagas. The latter two crops were used because their boron-deficiency symptoms were well known. Borax was mixed with complete fertilizers to give applications of borax of 5, 10, and 15 pounds to the acre on four farms.

In New York, 1938 was a relatively wet year and the amount of breakdown in beets was small. Practically no breakdown occurred in the beets in the replicated plots planted to various vegetables. Neither did boron-deficiency symptoms occur on the cauliflower, the rutabagas, or the other vegetables on these plots. No injury due to boron toxicity was noticed on the crops grown on the plots with 25 pounds of borax to the acre. The percentage of breakdown in the beets grown in the other experimental plots is shown in table 1. Applying 10 or 15 pounds of borax to the acre had relatively little effect on the percentage of beets showing symptoms of internal breakdown, although in some instances these amounts of borax tended to reduce the amount and severity of the breakdown. Many of the beets with breakdown were but slightly affected. As had been noted in 1936, very little injury of the growing point accompanied the breakdown in the root.

EXPERIMENTS IN 1939

The results obtained in 1938 and in the greenhouse in the spring of 1939 suggested the use of larger quantities of borax in the experimental work in 1939. Walker et al.⁵ reported that quantities of borax as high as 60 pounds to the acre gave much better control than did smaller quantities. In some instances they obtained consistent increases in stand as they increased the rate of borax application. Bouquet⁶ reduced breakdown with 20 pounds of borax to the acre.

Borax was applied at rates of 0, 12½, 25, 50, and 75 pounds to the acre on single plots 10 feet by 22 feet on 8 widely scattered fields. Hydrated lime at the rate of 1000 pounds to the acre, sulfur at 500 pounds to the acre, muriate of potash to supply 150 pounds of K₂O to the acre, and super-

⁵Walker, J. C., Jolivet, J. P., and McLean, J. G. Internal black spot of canning beets and its control. Canning age, 19:489-491. 1938.

⁶Bouquet, A. G. B. Determination of usefulness of boron in prevention of beet canker. Oregon State College. Mimeographed chart. 1938.

phosphate to give 150 pounds of P_2O_5 to the acre were similarly applied on adjacent plots. These applications were made by hand and were raked into the soil before the beet seed was sown. In all cases these applications supplemented the relatively boron-free fertilizer applied by the growers, the kind and quantity of which varied widely.

Borax was also applied in trenches alongside the row in 9 areas on 7 farms at rates of 0, $12\frac{1}{2}$, 25, and 50 pounds to the acre. This was done in the same way as in 1937 and 1938 soon after the beets were large enough to make this work possible.

Two growers used 8-16-14 fertilizer with which borax was mixed at the rate of 200 pounds to a ton of fertilizer. This mixture was used at the rate of 500 pounds to the acre, giving 50 pounds of borax to the acre. Similar fertilizer with no borax added was applied in the same fields. One grower (Harold Soper) applied an 8-16-14 fertilizer containing borax on his home garden planted to beans, corn, cucumbers, melons, lima beans, potatoes, and tomatoes, to supply 50 pounds of borax to the acre. Because many growers believed that side-dressing beets with nitrate of soda during the growing season reduced the amount of breakdown, synthetic nitrate of soda was applied at the rate of 200 pounds to the acre on small plots on several farms.

Data from the plots on which the borax and other materials were applied broadcast were taken by harvesting the beets in the two center rows of each plot, leaving 1 foot on each end of each row unharvested. Weight of the topped beets, total number of plants, and amount of internal breakdown were recorded. The latter was determined by slicing 50 beets selected at random from each plot. In order to have some arbitrary standard by which to distinguish between severe and slight breakdown, all beets with broken-down areas totaling more than $\frac{5}{8}$ inch in diameter were classed under *severe* breakdown. Before concluding that any beet was free from breakdown it was sliced at least 5 times.

Results

Rainfall in 1939 in the beet-growing section of New York was inadequate, and breakdown was severe on many farms. No injury resulting from boron toxicity was noted at any time during the growing season from any of the applications of borax, except on the beans grown on the garden plot treated with 50 pounds of borax to the acre. This injury was not severe and the beans produced a good crop.

TABLE 1. PERCENTAGE OF BEETS SHOWING BREAKDOWN IN 1938

Pounds of borax (acre basis)	Soper farm	Winburn farm	Post farm	Vosburg farm	Hughston farm	Jensen farm
None.....	23.4	21.5	12.2	3.8	11.0	9.1
5.....	20.0	27.0	9.4	8.2	10.9	12.4
10.....	28.8	16.6	3.1	0.0	6.3	6.5
15.....	20.5		4.8	1.2		7.6

Effect of treatments on stand of plants

The total number of plants per 40 feet of row on plots treated with varying quantities of borax, with lime, sulfur, etc. is shown in table 2. Although

there were more plants per row in plots with 75 pounds of borax to the acre than on those with a low or no application of borax, there was no consistent difference between the plots without borax and those receiving less than 75 pounds of borax to the acre.

The use of sulfur at the rate of 500 pounds to the acre decreased the stand in practically all instances, as shown in table 2. On the McLane farm the applications were made on the same day, but the east side of the field was planted shortly after the supplementary materials were applied, while the west side of the field was planted about two weeks later. The sulfur plot on the west side was one of those that did not show reduced stands as compared with other plots in the same areas.

TABLE 2. TOTAL NUMBER OF PLANTS TO 40 FEET OF ROW FOR THE VARIOUS TREATMENTS USED IN 1939 (MATERIALS APPLIED BROADCAST)

Treatment (acre basis)	Wickham farm		Flint farm		McLane farm		Salisbury farm	Average*
	East plot	West plot	South plot	North plot	East plot	West plot		
None.....	352	303	202	190	236	358	440	297.3
Borax, 12½ pounds.....	321	318	261	173	240	316	331	280.0
Borax, 25 pounds.....	375	389	223	205	247	335	353	303.9
Borax, 50 pounds.....	377	364	202	248	265	301	287	292.0
Borax, 75 pounds.....	361	340	385	307	291	358	382	346.3
Sulfur, 500 pounds.....	293	303	124	183	90	337	225	222.1
Lime, 1000 pounds.....	305	320	...	...	249	297	359	306.0
P ₂ O ₅ ,† 150 pounds.....	364	301	184	179	259	327	332	278.0
K ₂ O,† 150 pounds.....	339	305	220	201	213	388	415	297.3

*Difference for significance between any 2 treatment averages except lime: odds 19:1 = 44.07; odds 99:1 = 58.86.

†In addition to that supplied by the grower.

Effect of treatments on yields

The yields on the various farms varied widely, as shown in table 3. On the Salisbury and Wickham plots, yields averaged more than 15 tons to the acre. The average yield from the other plots less heavily fertilized was less than 5 tons per acre. There were no outstanding differences in

TABLE 3. BEET YIELDS, TONS PER ACRE, 1939 (BROADCAST APPLICATIONS)

Treatment (acre basis)	Wickham farm		Salisbury farm	Flint farm		McLane farm		Ledgerwood farm	Average*
	East plot	West plot		South plot	North plot	East plot	West plot		
Check.....	14.48	17.53	13.96	3.91	3.68	6.13	5.04	4.84	8.70
Borax, 12½ pounds.....	20.05	18.27	15.14	3.30	4.61	6.60	4.77	4.94	9.71
Borax, 25 pounds.....	19.68	16.34	14.30	4.67	4.78	7.08	4.56	4.82	9.53
Borax, 50 pounds.....	19.16	16.78	15.14	3.85	5.60	7.83	4.08	5.52	9.75
Borax, 75 pounds.....	18.34	16.19	13.51	4.43	8.17	7.49	5.31	5.60	9.88
Sulfur, 500 pounds.....	18.12	20.72	15.60	4.20	5.25	6.26	4.90	4.82	9.98
Lime, 1000 pounds.....	14.40	17.82	13.10	...	...	6.53	3.81	5.37	10.17
P ₂ O ₅ ,† 150 pounds.....	14.40	17.08	15.14	3.50	3.62	6.67	4.49	5.91	8.85
K ₂ O,† 150 pounds.....	14.55	17.97	15.30	4.32	3.73	6.40	5.58	6.22	9.26

*Difference for significance between any 2 treatment averages except lime: odds 19:1 = 1.23; odds 99:1 = 1.64.

†In addition to that supplied by the grower.

yields that could be attributed to the application of borax. Although the difference in average yields between the plots with no borax and those with 75 pounds to the acre was almost significant, it was due in part to the low yield from the east plot without borax on the Wickham farm. The markedly low yield on that plot, compared with those from plots without borax, on the other farms casts doubt on the results from the east plot on the Wickham farm.

Effect of treatments on internal breakdown

In general, all applications of borax applied broadcast before seeding reduced the amount and severity of breakdown, as compared with that found in beets grown in adjacent plots without borax. The degree of control with the different applications varied on the different fields, as shown in table 4.

Considering the average of fields, an application of $12\frac{1}{2}$ pounds of borax per acre reduced the number of beets showing breakdown from 52 per cent to 30 per cent, as compared with beets grown in plots which had not received borax. Increasing the application of borax to 50 pounds per acre reduced the amount of breakdown to 16 per cent; and in plots which received 75 pounds of borax per acre, 11 per cent of the beets showed some breakdown. Adding 150 pounds of K_2O or P_2O_5 or 500 pounds of sulfur per acre had no effect on the amount of breakdown.

Forty-one per cent of the beets grown in plots which did not receive borax showed severe-breakdown symptoms. The amount of severe breakdown was reduced to 22.5 per cent by supplying $12\frac{1}{2}$ pounds of borax per acre; 50 pounds per acre reduced it to 9.5 per cent; and 75 pounds per acre reduced it to 6.5 per cent. In only four of the eight fields did any beets show severe-breakdown symptoms in plots which had received 75 pounds of borax per acre.

There was less satisfactory control of internal breakdown by the use of borax on the three high-yielding fields, (Wickham farm, east and west plots, and Salisbury farm) than on the other five fields where the yields were low. In fact, in these five latter fields good commercial control of breakdown was obtained when 50 pounds of borax was applied per acre. A similar association between increased yields and the amount of breakdown was noted on a plot side-dressed with nitrate of soda on the Flint farm. This plot yielded 8.87 tons to the acre, while two adjacent plots without nitrogen averaged 3.15 tons to the acre. The amount of breakdown in beets grown in the nitrated plot was 32 per cent; breakdown in the beets grown in the plots not nitrated was 6 per cent. On plots in five other fields the beets made no apparent response to the nitrate side-dressing and yield data were not taken. However, there were no consistent differences in the amount of internal breakdown in the nitrated plots as compared with those not side-dressed; this was determined by slicing 50 beets from each plot. It is possible that the higher demand for boron on the plots with the larger yields reduced the supply of available boron in the soil to the point where even 75 pounds of borax per acre was insufficient to control breakdown effectively.

The amount of severe breakdown on the plot receiving 75 pounds of borax to the acre on the Salisbury farm raises the question whether borax will satisfactorily control breakdown during dry seasons. On this farm,

TABLE 4. PERCENTAGE OF BEETS SHOWING ANY BREAKDOWN, 1939
(BROADCAST APPLICATIONS)

Treatment (acre basis)	Wickham farm				Salisbury farm		Flint farm				McLane farm				Ledgerwood farm		Average*		
	East plot		West plot		Total	Severe	South plot		North plot		Total	Severe	East plot		West plot			Total	Severe
	Total	Severe	Total	Severe			Total	Severe	Total	Severe			Total	Severe	Total	Severe			
Check,	26	19	63	41	94	87	23	11	16	8	90	80	38	27	66	56	52.0	41.12	
Borax, 5 pounds, . . .	8	4	64	60	80	76	9	1	11	1	47	33	9	2	12	12	30.0	22.50	
Borax, 12½ pounds, . .	16	12	56	46	84	84	16	6	2	0	25	16	12	11	13	2	28.0	22.12	
Borax, 25 pounds, . . .	8	2	30	24	52	32	2	0	2	0	34	14	2	0	2	2	16.13	9.50	
Borax, 50 pounds, . . .	12	8	20	6	46	32	0	0	2	0	6	4	2	0	1	6.25	11.00	6.25	
Borax, 75 pounds, . . .	14	8	76	62	92	90	38	22	20	12	72	60	52	42	40	16	50.5	39.00	
Sulfur, 500 pounds	18	12	78	68	100	96	1	1	2	88	70	46	32	18	62	32	65.33	52.00	
Lime, 1 ton,	24	16	64	44	96	90	24	14	16	12	58	44	32	34	48	8	45.25	30.75	
P.O. ₅ , † 150 pounds, . .	28	22	62	38	98	96	22	8	16	4	72	46	44	36	80	58	52.75	38.50	
K.O., † 150 pounds, . .																			

* Difference for significance between any two treatment averages except lime; odds 19:1 = 9.74 for total and 11.89 for severe.

† Difference for significance between lime and any other treatment; odds 19:1 = 10.53 for total and 15.35 for severe.

‡ In addition to that supplied by the grower.

on the plots without borax, 94 per cent of the beets showed some breakdown and 87 per cent of them were severely injured. On the plot with 75 pounds of borax to the acre, the corresponding figures were 46 and 32 per cent. The foliage of the beets in the untreated plots showed evidence of boron deficiency three weeks before the data were taken. Data taken at that time, by cutting beets in the guard rows of the plot with 75 pounds of borax to the acre, indicated that had the plot been harvested at that date the amount of severe breakdown would have been much less.

On three farms where borax was applied at the rate of 5 pounds to the acre, breakdown was markedly reduced as compared with the plots without borax. On the late-planted plots on the McLane farm, the amount of severe breakdown was reduced from 27 per cent in plots without borax to 2 per cent in the plots with 5 pounds of borax to the acre.

Effect of row applications of borax on internal breakdown

Row applications of borax reduced the average amount of breakdown on seven farms from almost 53 per cent in areas without borax to less than 20 per cent on plots receiving 50 pounds to the acre, as shown in table 5. Applications made before foliage symptoms of boron deficiency were evident on August 24, at the rate of 25 and 50 pounds of borax to the acre on the Wickham farm did not reduce the amount of breakdown. The soil was very dry when the application was made and remained so for two weeks. This fact undoubtedly accounted for the lack of control of the breakdown and indicates that delaying the application of borax until late in the season is not advisable.

TABLE 5. PERCENTAGE OF BEETS SHOWING ANY BREAKDOWN, 1939
(ROW APPLICATIONS)

Treatment (pounds of borax to the acre)	Kindle- berger farm	Jensen farm			Carr farm	McLane farm		Andsley farm	Vosburg farm	Average*
		West field, west plot	West field, east plot	South plot		South plot	North plot			
Check.....	45	82	88	28	28	79	64	23	38	52.78
12½.....	25	55	70	28	20	52	26	11	24	34.56
25.....	27	22	56	24	6	58	20	4	20	26.33
50.....	17	28	44	10	2	36	10	12	18	19.67

*Difference for significance between any 2 treatment averages: odds 19:1 = 8.75; odds 99:1 = 11.85.

EXPERIMENTS IN 1940

The majority of beet growers in the Ontario County area used borax at the recommended rate of 50 pounds to the acre in 1940. One grower (Earl Noble) used 120 pounds to the acre on a small plot. The experimental work with beets was restricted to the use of borax at the rate of 0, 25, 50, 75, and 100 pounds to the acre on replicated plots on four farms. On one of these (Salisbury farm) quantities of borax similar to those used in 1939 were applied on the same plots used in 1939, and on adjacent plots borax was used at the above rates. Experiments were made on this farm because of the relatively poor control of breakdown with borax in 1939.

In an attempt to determine whether relatively heavy application of

borax in 1939 had an injurious effect on crops in 1940, red kidney beans were planted on four farms in the plots treated with 50 and with 75 pounds of borax to the acre in 1939, and also in adjacent areas not fertilized with borax in 1939. These fields had been planted to other crops, one of them with beets which had been fertilized with 50 pounds of borax to the acre. Beans were used for these toxicity studies because many experimenters have found them easily injured by borax applications. Lorenz, in unpublished work, found that beans planted in the greenhouse after beets, in soils from Ontario County, were injured if 25 pounds or more of borax had been used for the beets. It must be kept in mind that in these experiments the soil was not leached as it would be under field conditions.

Results

The 1940 season through June was one of excessive rainfall, but July and August were months of subnormal moisture. No indications of injury to beets due to borax toxicity were noted at any time during the season. No beets on two of the farms showed any symptoms of breakdown. On the Post farm, 100 pounds of borax to the acre reduced breakdown to an average of 1 per cent slight breakdown, as compared with 32 per cent of breakdown in plots without borax. There was but 2 per cent of severe breakdown on the plots fertilized with 75 pounds of borax to the acre.

As in 1939 on the Salisbury farm, breakdown was very severe. One hundred pounds of borax per acre reduced the amount of breakdown to 28 per cent, as compared with 83 per cent in plots without borax. The corresponding amounts of severe breakdown were 14 per cent and 73 per cent. The percentage of beets showing breakdown in the plots on the Post and on the Salisbury farms is shown in table 6. There was relatively little difference in the respective control obtained on the plots fertilized with 25, 50, and 75 pounds of borax in 1939 and in 1940 and on those with similar amounts in 1940 only.

TABLE 6. PERCENTAGE OF BEETS SHOWING BREAKDOWN, 1940
(BROADCAST APPLICATIONS)

	No borax per acre		25 lbs. borax per acre		50 lbs. borax per acre		75 lbs. borax per acre		100 lbs. borax per acre	
	Total	Severe	Total	Severe	Total	Severe	Total	Severe	Total	Severe
Post farm.	32	22	17	11	14	6	8	2	1	1
Salisbury farm.	83	73	59	47	31	24	26	16	28	14
Salisbury farm*. . .	..	..	38	32	24	16	32	20	..	..

*Plots received same application of borax in 1939.

The beans on the plots fertilized with 50 pounds of borax in 1940 showed some injury on July 2, 11 days after sowing, and severe injury on July 11. The injury was more severe than that noted in 1939 on beans fertilized with 50 pounds of borax to the acre. The beans on plots with 75 pounds of borax to the acre in 1939 and none in 1940 showed some indications of very slight injury on July 17. No reduction in the size of the plants was evident and the appearance of the plants on August 1 and September 3 indicated that no permanent injury had resulted.

GREENHOUSE EXPERIMENTS

Greenhouse experimental work included culture-solution experiments to determine the effect of very low levels of boron on breakdown and the use of borax on soils from fields where breakdown was severe.

These experiments were carried on in the greenhouses of the Department of Vegetable Crops, Cornell University, using a strain of the Detroit Dark Red variety of beet. Distilled water was used for all of the work. The chemicals used for the nutrient-solution experiments were of C.P. grade.

CULTURE-SOLUTION EXPERIMENTS

In 1938 and 1939 beets were grown in sand with solutions containing 0, 0.05, 0.1, and 0.2 part per million of boron, supplied as borax ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10 \text{H}_2\text{O}$). All treatments were in duplicate.

Three-gallon earthenware crocks which had been paraffined previously were used for containers. Five beets were left to mature in each crock. Each crock contained 42 pounds of quartz sand which had been thoroughly washed with tap water and then leached with distilled water. The sand had a water-holding capacity of 22 per cent, which was equivalent to slightly more than four liters of solution per container. The sand saved from the 1938 experiments was used again in 1939 after being thoroughly leached with distilled water. At ten-day intervals two liters of nutrient solution was applied to each container. This solution had the following composition: $\text{CaNO}_3 - 0.0052 \text{ M.}$, $\text{KH}_2\text{PO}_4 - 0.018 \text{ M.}$, $\text{MgSO}_4 - 0.015 \text{ M.}$, Fe - 10 ppm from $\text{Fe}_2(\text{SO}_4)_3$, Mn - 10 ppm from MnCl_2 , Zn - 10 ppm from ZnSO_4 , Cu - 0.2 ppm from CuSO_4 .

Subsequent experiments with beets have shown that these quantities of Zn, Cu, and Mn are larger than required for the normal growth of beets.

Cultures were leached with four one-liter portions of distilled water each time before the nutrient solution was supplied. Additional distilled water was supplied as needed between the times the nutrient solutions were applied.

Seed was sown on February 12 in 1938 and on February 2 in 1939. The plants were harvested on May 16 in 1938 and on April 15 in 1939. In figure 3 is shown the relative growth of the 1938 planting at harvest time. Similar growth was obtained in 1939. There were noticeable differences in growth in the various treatments from the time the plants came up. Plants grown without boron failed to develop true leaves and died soon after the cotyledons were expanded. In 1938 the plants grown without boron and with 0.05 ppm of boron showed dead terminals at harvest time, but in 1939 all plants had dead terminals except those supplied with the maximum amount of boron. Leaves of all plants grown in the lower boron series showed an accumulation of anthocyanin, especially in the younger leaves. Leaves of plants supplied with 0.2 ppm of boron were still green at harvest time.

In table 7 are shown the incidence and severity of physiological breakdown in the beet roots at harvest. In 1938 the amount of breakdown in the roots varied from 100 per cent when the beets were grown in the 0.05 ppm boron series to 20 per cent for beets grown in solutions containing 0.2 ppm of boron. The percentage of beets showing severe breakdown varied from 100 when grown in solutions containing 0.05 ppm of boron to 0 when

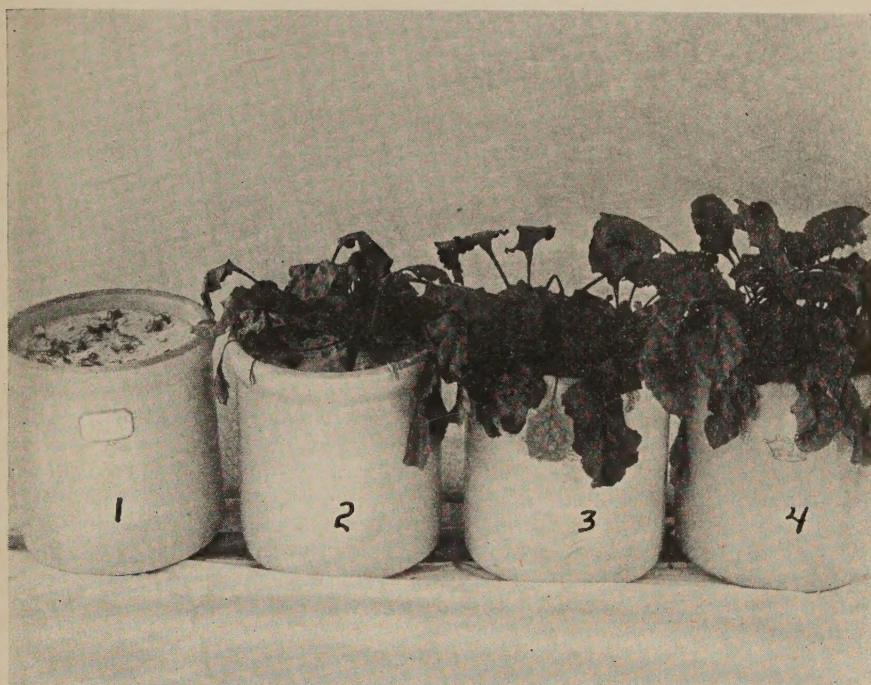


FIGURE 3. BEETS GROWN IN SAND SUPPLIED WITH NUTRIENT SOLUTION CONTAINING: 1, NO BORON; 2, 0.05 PART PER MILLION BORON; 3, 0.1 PART PER MILLION BORON; AND 4, 0.2 PART PER MILLION BORON

grown in solutions with 0.2 ppm of boron. In 1939 the breakdown was reduced from 90 per cent in beets grown with 0.05 ppm of boron to 40 per cent with 0.2 ppm boron. The amount of severe breakdown declined from 80 per cent for beets grown with 0.05 ppm of boron to 10 per cent for beets grown with 0.2 ppm of boron. Roots of plants grown in solutions containing 0.05 ppm of boron were black throughout the interior. The exterior of some of these roots consisted of a mass of jell or slime. Roots

TABLE 7. PERCENTAGE OF BEETS SHOWING BREAKDOWN WHEN GROWN WITH VARYING AMOUNTS OF BORON

Amount of boron used (parts per million)	1938 crop			1939 crop		
	Per cent of beets showing breakdown			Per cent of beets showing breakdown		
	Total	Severe	None	Total	Severe	None
None.....	*	*	*	*	*	*
0.05.....	100	100	0	90	80	10
0.10.....	77	44	22	90	70	10
0.20.....	20	0	80	40	10	60

*No growth.

of plants grown in 0.2 ppm of boron rarely showed more than one or two small black spots.

EXPERIMENTS IN SOILS

Soils were collected in November, 1938, from three fields where internal breakdown had been prevalent the previous summer. Three-gallon earthenware crocks were used as containers. Each crock contained 45 pounds of oven-dry soil. The borax treatments of 0, 12½, 25, and 50 pounds per acre were in quadruplicate for each soil; other treatments were in duplicate. Five beets were left to mature in each container. A 5-8-5 fertilizer at the rate of one ton per acre was applied to the soil in each crock. The application was divided so that one-half of the fertilizer was applied before the seed was sown and one-half when the plants were about eight inches tall.

Seed was sown on January 1, 1939, and the plants were harvested on May 25, 1939. The yields from the various treatments are given in table 8. There was relatively little difference in yield due to treatment and no difference between the no-borax treatment and any borax treatment. One thousand pounds of sulfur per acre was slightly toxic in the soil from the Jensen farm. The addition of one ton of sodium silicate increased the yield of roots and total plants in each of the three soils. Leaves of plants grown in the no-borax treatment in soil from the Jensen farm were darker in color and showed more red than the leaves of plants grown in containers to which boron was applied.

TABLE 8. WEIGHT OF BEET PLANTS IN GRAMS PER CONTAINER IN GREENHOUSE EXPERIMENTS WITH SOILS FROM ONTARIO COUNTY

Treatment (acre basis)	Post farm			Jensen farm			Soper farm		
	Tops	Roots	Total	Tops	Roots	Total	Tops	Roots	Total
None.....	244	256	500	216	306	522	244	335	579
Borax, 12½ pounds.....	270	269	539	236	305	541	271	276	547
Borax, 25 pounds.....	257	286	543	238	345	583	224	371	595
Borax, 50 pounds.....	267	306	573	256	289	545	226	346	572
Borax, 75 pounds.....	220	212	432	175	207	382	244	361	605
Sulfur, 500 pounds.....	154	225	379	218	280	498	181	233	414
Sulfur, 1000 pounds.....	202	209	411	219	186	405	225	284	509
Calcium oxide, 2000 pounds.....	226	326	552	244	326	570	246	328	574
Sodium silicate, 2000 pounds.....	287	396	683	222	444	666	286	447	733
Calcium chloride*.....	358	206	564	325	261	586	360	221	581

*Equivalent in calcium to that in 2000 pounds of calcium oxide.

The effect of treatment on breakdown is shown in table 9. The soil from the Post farm failed to produce any breakdown symptoms, except in the no-borax treatment and in the treatment of 12½ pounds of borax per acre. In the soil from the Jensen farm, breakdown was reduced from 50 per cent in the no-borax treatment to 0 in the borax treatments of 50 and of 75 pounds per acre. One thousand pounds of sulfur reduced the amount of breakdown but these beets were smaller owing to toxicity. The addition of calcium chloride likewise reduced the size of the plants and the roots showed less breakdown than did those in the 0-borax treatment.

No definite conclusions can be drawn from experiments with the soil

TABLE 9. PERCENTAGE OF BEETS SHOWING BREAKDOWN IN GREENHOUSE EXPERIMENTS WITH SOILS FROM ONTARIO COUNTY

Treatment (acre basis)	Soil		
	Post farm	Jensen farm	Soper farm
None.....	5	50	20
Borax, 12½ pounds.....	5	26	0
Borax, 25 pounds.....	0	27	12
Borax, 50 pounds.....	0	0	10
Borax, 75 pounds.....	0	0	0
Sulfur, 500 pounds.....	0	44	0
Sulfur, 1000 pounds.....	0	20	11
Calcium oxide, 2000 pounds.....	0	30	10
Sodium silicate, 2000 pounds.....	0	50	40
Calcium chloride = Ca in 1 ton CaO.....	0	20	0

from the Soper farm. One-half as many beets in soils with the borax application of 50 pounds per acre showed breakdown as those in the pots without borax, but no breakdown occurred in beets in soils with 12½ pounds of borax to the acre. The addition of sodium silicate produced the highest percentage of internal breakdown in this soil, owing perhaps to the fact that it increased the size of root and made for a greater boron requirement.

SUMMARY AND RECOMMENDATIONS

Four important factors that make boron deficiency of beets a serious problem for beet growers on Ontario and similar soils of New York are, high boron requirement of the beet, alkaline soil reaction, use of little or no manure, and deficiencies of soil moisture. Interaction between these and other factors responsible for internal breakdown are little understood at the present time. The evidence indicates that when high yields accompany unfavorable conditions, internal breakdown is likely to be more severe than if yields are low as a result, for example, of inadequate fertilization.

Although under some conditions quantities of borax as small as 5 pounds to the acre may greatly reduce the amount of internal breakdown, quantities as large as 50 pounds to the acre will not eliminate the trouble if conditions which make for severe breakdown are present. However, results obtained to date indicate that 50 pounds of borax to the acre will give satisfactory commercial control, especially if growers harvest the crop as soon as symptoms of breakdown appear. Observations indicate that foliage symptoms are not reliable indicators of breakdown during some seasons.

Borax thoroughly mixed with the fertilizer, to supply 50 pounds of borax to the acre, and applied before the beets are planted, is recommended as a standard application for high-lime soils that have not been heavily fertilized with borax in the past. To avoid poor physical condition and possible loss of ammonia, the fertilizer should be applied soon after mixing. More difficulties with poor physical condition are likely to be encountered when using double-strength fertilizers than with single strength fertilizers. If application cannot be made soon after mixing, this fact may reduce the considerable savings made possible by the use of double-strength analyses such as 8-16-16. It should be kept in mind that these recommendations

are for beets grown on alkaline soils. Quantities of borax as large as 50 pounds to the acre may be injurious if used for beets on soils more acid than those used in these experiments, and are almost certain to be injurious for boron-sensitive crops, such as beans, grown on any soil.

Until more evidence is available it may be advisable to grow boron-tolerant crops such as cabbage rather than boron-sensitive crops such as beans on fields fertilized with 50 pounds of borax to the acre for beets the previous year.